Annex D

Methodology for Estimating Methane Emissions from Coal Mining

The methodology for estimating methane emissions from coal mining consists of two distinct steps. The first step addresses emissions from underground mines. For these mines, emissions were estimated on a mine-by-mine basis and then are summed to determine total emissions. The second step of the analysis involved estimating methane emissions for surface mines and post-mining activities. In contrast to the methodology for underground mines, which used mine-specific data, the methodology for estimating emissions from surface mines and post-mining activities consists of multiplying basin-specific coal production by basin specific emissions factors.

Step 1: Estimate Methane Liberated and Methane Emitted from Underground Mines

Underground mines liberate methane from ventilation systems and from degasification systems. Some mines recover and use methane liberated from degasification systems, thereby reducing methane emissions to the atmosphere. Total methane emitted from underground mines equals methane liberated from ventilation systems, plus methane liberated from degasification systems, minus methane recovered and used.

Step 1.1 Estimate Methane Liberated from Ventilation Systems

All coal mines use ventilation systems for several air quality purposes and to ensure that methane levels remain within safe concentrations. Many coal mines do not have detectable methane emissions, while others emit several million cubic feet per day (MMCFD) from their ventilation systems. On a quarterly basis, the U.S. Mine Safety and Health Administration (MSHA) measures methane emissions levels at underground mines. MSHA maintains a database of measurement data from all underground mines with detectable levels of methane in their ventilation air.[6] Based on the four quarterly measurements, MSHA estimates average daily methane liberated at each of the underground mines with detectable emissions.

For the years 1990 through 1996, EPA obtained MSHA emissions data for a large but incomplete subset all mines with detectable emissions. This subset includes mines emitting at least 0.1 MMCFD for some years and at least 0.5 MMCFD for other years, as shown in Table D-1. Well over 90 percent of all ventilation emissions are concentrated in these subsets. For 1997, EPA obtained the complete MSHA database for all 586 mines with detectable methane emissions. These mines were assumed to account for 100 percent of methane liberated from underground mines.

Using this complete 1997 database, the portion of total emissions accounted for by mines emitting more and less than 0.1 MMCFD or 0.5 MMCFD was estimated. (see Table D-1). These proportions were then applied to the years 1990 through 1996 to account for the less than 10 percent of mines without MSHA data.

Average daily methane emissions were multiplied by 365 days per year to determine annual emissions for each mine. Total ventilation emissions for these mines were estimated by summing emissions from individual mines.

[6] MSHA records coal mine methane readings with concentrations of greater than 50 ppm (parts per million) methane. Readings below this threshold are considered non-detectable.

Table D-1: Mine-Specific Data Used to Estimate Ventilation Emissions

Year	Individual Mine Data Used
1990	All Mines Emitting at Least 0.1 MMCFD (Assumed to Account for 97.8% of Total)*
1991	1990 Emissions Factors Used Instead of Mine Specific Data
1992	1990 Emissions Factors Used Instead of Mine Specific Data
1993	All Mines Emitting at Least 0.1 MMCFD (Assumed to Account for 97.8% of Total)*
1994	All Mines Emitting at Least 0.1 MMCFD (Assumed to Account for 97.8% of Total)*
1995	All Mines Emitting at Least 0.5 MMCFD (Assumed to Account for 94.1% of Total)*
1996	All Mines Emitting at Least 0.5 MMCFD (Assumed to Account for 94.1% of Total)*
1997	All Mines with Detectable Emissions (Assumed to Account for 100% of Total)

*Assumption based on complete set of individual mine data collected for 1997.

Step 1.2 Estimate Methane Liberated from Degasification Systems

Over 20 U.S. coal mines use degasification systems in addition to their ventilation systems for methane control. Coal mines use several different types of degasification systems to remove methane, including vertical wells and horizontal boreholes recover methane prior to mining of the coal seam. Gob wells and cross-measure boreholes recover methane from the overburden (i.e., GOB area) after mining of the seam (primarily in longwall mines).

MSHA collects information about the presence and type of degasification systems in some mines, but does not collect quantitative data on the amount of methane liberated. Thus, the methodology estimated degasification emissions on a mine-by-mine basis based on other sources of available data. Many of the coal mines employing degasification systems have provided EPA with information regarding methane liberated from their degasification systems. For these mines, this reported information was used as the estimate. In other cases in which mines sell methane recovered from degasification systems to a pipeline, gas sales were used to estimate methane liberated from degasification systems (see Step 1.3). Finally, for those mines that do not sell methane to a pipeline and have not provided information to EPA, methane liberated from degasification systems was estimated based on the type of system employed. For example, for coal mines employing gob wells and horizontal boreholes, the methodology assumes that degasification emissions account for 40 percent of total methane liberated from the mine.

Step 1.3: Estimate Methane Recovered from Degasification Systems and Used (Emissions Avoided)

In 1996, all 12 active U.S. coal mines that had developed methane recovery and use projects sold the recovered methane to a pipeline. One coal mine also used some recovered methane in a thermal dryer in addition to selling gas to a pipeline. Where available, state agency gas sales data were used to estimate emissions avoided for these projects. Emissions avoided were attributed to the year in which the coal seam was mined. For example, if a coal mine recovered and sold methane using a vertical well drilled five years in advance of mining, the emissions avoided associated with those gas sales were attributed to the year during which the well was mined-through (five years after the gas was sold). In order to estimate emissions avoided for those coal mines using degasification methods that recover methane in advance of mining, information was needed regarding the amount of gas recovered and the number of years in advance of mining that wells were drilled. In most cases, coal mine operators provided EPA with this information, which was then used to estimate emissions avoided for a particular year. Additionally, several state agencies made production data available for individual wells. For some mines, this individual well data were used to assign gas sales from individual wells to the appropriate emissions avoided year.

Step 2: Estimate Methane Emitted from Surface Mines and Post-Mining Activities

Mine-specific data was not available for estimating methane emissions from surface coal mines or for post-mining activities. For surface mines and post-mining activities, basin-specific coal production was multiplied by a basin-specific emission factors to determine methane emissions.

Step 2.1: Define the Geographic Resolution of the Analysis and Collect Coal Production Data

The first step in estimating methane emissions from surface mining and post-mining activities was to define the geographic resolution of the analysis and to collect coal production data at that level of resolution. The U.S. analysis was conducted by coal basin as defined in Table D-2.

The Energy Information Agency (EIA) Coal Industry Annual reports state- and county-specific underground and surface coal production by year. To calculate production by basin, the state level data were grouped into coal basins using the basin definitions listed in Table D-2. For two states—West Virginia and Kentucky—county-level production data was used for the basin assignments because coal production occurred from geologically distinct coal basins within these states. Table D-2 presents coal basin definitions by basin and by state. Table D-3 presents the coal production data aggregated by basin.

Step 2.2: Estimate Emissions Factors for Each Emissions Type

Emission factors for surface mined coal were developed from the *in situ* methane content of the surface coal in each basin. Based on an analysis presented in EPA (1993), the surface mining emission factors used were from 1 to 3 times the average *in situ* content in the basin. Furthermore, the post-mining emission factors used were assumed to be 25 to 40 percent of the average *in situ* content in the basin. Table D-4 presents the average *in situ* content for each basin, along with the resulting emission factor estimates.

Step 2.3: Estimate Methane Emitted

The total amount of methane emitted was calculated by multiplying the coal production in each basin by the appropriate emission factors.

Total annual methane emissions is equal to the sum of underground mine emissions plus surface mine emissions plus post-mining emissions. Table D-5 and Table D-6 present estimates of methane liberated, methane used, and methane emissions for 1990 through 1997 (1997 is a preliminary estimate).

Table D-2: Coal Basin Definitions by Basin and by State

Basin	States
Northern Appalachian Basin	Maryland, Ohio, Pennsylvania, West VA North
Central Appalachian Basin	Kentucky East, Tennessee, Virginia, West VA South
Warrior Basin	Alabama
Illinois Basin	Illinois, Indiana, Kentucky West
South West and Rockies Basin	Arizona, California, Colorado, New Mexico, Utah
North Great Plains Basin	Montana, North Dakota, Wyoming
West Interior Basin	Arkansas, Iowa, Kansas, Louisiana, Missouri, Oklahoma, Texas
Northwest Basin	Alaska, Washington
State	**Basin**
Alabama	Warrior Basin
Alaska	Northwest Basin
Arizona	South West And Rockies Basin
Arkansas	West Interior Basin
California	South West And Rockies Basin
Colorado	South West And Rockies Basin
Illinois	Illinois Basin
Indiana	Illinois Basin
Iowa	West Interior Basin
Kansas	West Interior Basin
Kentucky East	Central Appalachian Basin
Kentucky West	Illinois Basin
Louisiana	West Interior Basin
Maryland	Northern Appalachian Basin
Missouri	West Interior Basin
Montana	North Great Plains Basin
New Mexico	South West And Rockies Basin
North Dakota	North Great Plains Basin
Ohio	Northern Appalachian Basin
Oklahoma	West Interior Basin
Pennsylvania.	Northern Appalachian Basin
Tennessee	Central Appalachian Basin
Texas	West Interior Basin
Utah	South West And Rockies Basin
Virginia	Central Appalachian Basin
Washington	Northwest Basin
West Virginia South	Central Appalachian Basin
West Virginia North	Northern Appalachian Basin
Wyoming	North Great Plains Basin

Table D-3: Annual Underground Coal Production (thousand short tons)

Underground Coal Production

Basin	1990	1991	1992	1993	1994	1995	1996
Northern Appalachia	103,865	103,450	105,220	77,032	100,122	98,103	106,729
Central Appalachia	198,412	181,873	177,777	164,845	170,893	166,495	171,845
Warrior	17,531	17,062	15,944	15,557	14,471	17,605	18,217
Illinois	69,167	69,947	73,154	55,967	69,050	69,009	67,046
S. West/Rockies	32,754	31,568	31,670	35,409	41,681	42,994	43,088
N. Great Plains	1,722	2,418	2,511	2,146	2,738	2,018	2,788
West Interior	105	26	59	100	147	25	137
Northwest	0	0	0	0	0	0	0
Total	**423,556**	**406,344**	**406,335**	**351,056**	**399,102**	**396,249**	**409,850**

Surface Coal Production

Basin	1990	1991	1992	1993	1994	1995	1996
Northern Appalachia	60,761	51,124	50,512	48,641	44,960	39,372	39,788
Central Appalachia	94,343	91,785	95,163	94,433	106,129	106,250	108,869
Warrior	11,413	10,104	9,775	9,211	8,795	7,036	6,420
Illinois	72,000	63,483	58,814	50,535	51,868	40,376	44,754
S. West/Rockies	43,863	42,985	46,052	48,765	49,119	46,643	43,814
N. Great Plains	249,356	259,194	258,281	275,873	308,279	331,367	343,404
West Interior	64,310	61,889	63,562	60,574	58,791	59,116	60,912
Northwest	6,707	6,579	6,785	6,340	6,460	6,566	6,046
Total	**602,753**	**587,143**	**588,944**	**594,372**	**634,401**	**636,726**	**654,007**

Total Coal Production

Basin	1990	1991	1992	1993	1994	1995	1996
Northern Appalachia	164,626	154,574	155,732	125,673	145,082	137,475	146,517
Central Appalachia	292,755	273,658	272,940	259,278	277,022	272,745	280,714
Warrior	28,944	27,166	25,719	24,768	23,266	24,641	24,637
Illinois	141,167	133,430	131,968	106,502	120,918	109,385	111,800
S. West/Rockies	76,617	74,553	77,722	84,174	90,800	89,637	86,902
N. Great Plains	251,078	261,612	260,792	278,019	311,017	333,385	346,192
West Interior	64,415	61,915	63,621	60,674	58,938	59,141	61,049
Northwest	6,707	6,579	6,785	6,340	6,460	6,566	6,046
Total	**1,026,309**	**993,487**	**995,279**	**945,428**	**1,033,503**	**1,032,975**	**1,063,857**

Source: EIA (1990-96), Coal Industry Annual. U.S. Department of Energy, Washington, D.C., Table 3.
Note: Totals may not sum due to independent rounding.

Table D-4: Surface and Post-Mining Coal Emission Factors (ft^3 per short ton)

	Surface Average *in situ*	Underground Average *in situ*	Surface Mine Factors			Post-Mining Surface Factors			Post Mining Underground		
Basin	Content	Content	Low	Mid	High	Low	Mid	High	Low	Mid	High
Northern Appalachia	49.3	49.3	49.3	98.6	147.9	12.3	16.0	19.7	12.3	16.0	19.7
Central Appalachia	49.3	49.3	49.3	98.6	147.9	12.3	16.0	19.7	12.3	16.0	19.7
Warrior	49.3	49.3	49.3	98.6	147.9	12.3	16.0	19.7	12.3	16.0	19.7
Illinois	39.0	39.0	39.0	78.0	117.0	9.8	12.7	15.6	9.8	12.7	15.6
S. West/Rockies	15.3	15.3	15.3	30.6	45.9	3.8	5.0	6.1	3.8	5.0	6.1
N. Great Plains	3.2	3.2	3.2	6.4	9.6	0.8	1.0	1.3	0.8	1.0	1.3
West Interior	3.2	3.2	3.2	6.4	9.6	0.8	1.0	1.3	0.8	1.0	1.3
Northwest	3.2	3.2	3.2	6.4	9.6	0.8	1.0	1.3	0.8	1.0	1.3

Source: EPA (1993), Anthropogenic Methane Emissions in the United States: Estimates for 1990, Report to Congress, U.S. Environmental Protection Agency, Air and Radiation, April.

Table D-5: Underground Coal Mining Methane Emissions (billion cubic feet)

Activity	1990	1991	1992	1993	1994	1995	1996	1997[b]
Ventilation Output	112	NA	NA	95	96	102	90	96
Adjustment Factor for Mine Data[a]	97.8%	NA	NA	97.8%	97.8%	91.4%	91.4%	100.0%
Ventilation Liberated	114	NA	NA	97	98	111	99	96
Degasification System Liberated	57	NA	NA	49	50	50	51	57
Total Underground Liberated	171	164	162	146	149	161	150	153
Recovered & Used	(15)	(15)	(19)	(24)	(29)	(31)	(35)	(42)
Total	**156**	**149**	**142**	**121**	**119**	**130**	**115**	**112**

[a] Refer to Table D-1

[b] Preliminary estimate.

Note: Totals may not sum due to independent rounding.

Table D-6: Total Coal Mining Methane Emissions (billion cubic feet)

Activity	1990	1991	1992	1993	1994	1995	1996	1997*
Underground Mining	156	149	142	121	119	130	115	112
Surface Mining	25	23	23	23	24	22	23	24
Post-Mining (Underground)	33	31	30	27	30	30	31	30
Post-Mining (Surface)	4	4	4	4	4	4	4	4
Total	**218**	**207**	**200**	**175**	**177**	**185**	**172**	**170**

* Preliminary estimate

Note: Totals may not sum due to independent rounding.